Pak. J. Weed Sci. Res. 17(2): 111-123, 2011

EVALUATING SEQUENTIAL APPLICATION OF PRE AND POST EMERGENCE HERBICIDES IN DRY SEEDED FINE RICE

Abdul Khaliq[1*], Amar Matloob[1], Hafiz Muhammad Shafiq[1], Zahid Ata Cheema[1] and Abdul Wahid[2]

ABSTRACT

A study was conducted to evaluate the efficacy of pre and post emergence herbicides applied either alone or in a sequence for weed control in dry seeded fine rice cv. Super basmati. Three herbicides namely Stomp 455CS (pendimethalin) at 1650 g a.i. ha^{-1} as pre-emergence, Nominee 100SC (bis-pyribac sodium) and Ryzelan 240SC (penoxsulam) at 30 and 15 g a.i. ha^{-1} respectively, were used as early post emergence (15 DAS). Pendimethalin was also followed by either of these herbicides. A weedy check and weed free treatments were maintained for comparison. Maximum paddy yield (2.79 t ha^{-1}) and net benefit of Rs. 83712 ha^{-1} were recorded where pendimethalin was followed by penoxsulam. Results indicated that pendimethalin followed by post emergence application of bispyribac sodium and penoxsulam gave more than 80% reduction in weed density and weed dry weight over control. Moreover, sequential applications of herbicides were better than alone in dry seeded rice.

Key words: Weed suppression, herbicides, rice yield, kernel quality.

INTRODUCTION

Direct seeding of rice has potential for attaining better water utilization and eliminating the edaphic conflict in rice-wheat cropping system of Punjab. Heavy weed infestation and shifts in weed population are major constraints in the sustainability of direct seeded rice (DSR). An appropriate weed management strategy has always been a major focus and key element to make DSR a success. Such a strategy is of utmost significance to improve yield, quality and minimize production costs as well. Traditionally, weeds are controlled through cultural and/or chemical methods. Manual weeding, though effective is getting increasingly difficult due to labor scarcity, rising wages and its dependence on weather conditions. Moreover, allowing weeds to reach sufficient size to be pulled out and the presence of

---

[1] Department of Agronomy, University of Agriculture, Faisalabad.
[2] Department of Botany, University of Agriculture, Faisalabad.
[*] E-mail: khaliquaf@gmail.com

perennial weeds that fragment on pulling are other related concerns (Rao *et al*., 2007). Thus, herbicides usage seems indispensable for weed management in direct seeded rice. Although DSR has been under practice in many regions of the world (Rao *et al*., 2007), yet its adoption in Pakistan has been restricted due to unavailability of a successful weed control strategy available locally.

Several studies (Gitsopoulos and Froud-Williams, 2004; Adigun *et al*., 2005; Singh *et al*., 2006; Mann *et al*., 2007; Singh *et al*., 2008; Mahajan *et al*., 2009) have concluded that chemical weed control is feasible as it is quick, easy and economical. Singh *et al*. (2006) suggested that both pre and post emergence herbicides, if properly used were quite effective in suppressing weeds in DSR. However, contrarily to other upland cereals, single application of a particular herbicide seldom furnishes adequate weed control in DSR. In DSR, permanent flood establishment can be done 4-6 weeks after sowing. Appropriate weed control during this period is essential to maximize grain yield. Thus, two herbicide applications are recommended in DSR, i.e., one before or after sowing and other at flooding (Kim and Ha, 2005). Pendimethalin, benthiocarb and quinclorac can control annual grass and broad-leaved weed species due to their residual activity in soil. In this regard, pendimethalin and benthiocarb should be used once the rice seed has imbibed water but prior to the emergence of rice and weeds (Jordan *et al*., 1998). Subsequent weed flushes can then be controlled by a suitable post emergence herbicide. Skipping post emergence herbicide treatment might cause a grain yield loss of 9-60% in DSR (McCauley *et al*., 2005). Rao *et al*. (2007) reported many options of post emergence herbicides like bis-pyribac sodium, penosulam, pyrazosulfuron, bentazone, bensulfuron, carfentrazone, clomazone, cyhalofop, molinate, propanil and fenoxaprop to be used in DSR. Little information is available about the effectiveness of any of the above mentioned herbicides under local agro-environments in Pakistan. Thus, present study was designed to assess the efficacy of sole and sequential application of pre and post emergence herbicides for selective and season-long weed control in DSR under agro-climatic conditions of Faisalabad-Pakistan.

MATERIALS AND METHODS

Site

The proposed study was conducted at Agronomic Research Farm, University of Agriculture Faisalabad, (31.25° N latitude, 73.09° E longitude, 184 m above sea level). Soil of experimental site belongs to Lyallpur soil series (Aridisol-fine-silty, mixed, hyperthermic Ustalfic, Haplargid in USDA classification and Haplic Yermosols in FAO classification). The pH of saturated soil paste was 7.6 and total soluble salts were 0.79 dS m^{-1}. Organic matter, total nitrogen, available phosphorus and potassium were 0.71%, 0.062%, 13.1 ppm, and 179 ppm, respectively. Due to high evapo-transpiration, Faisalabad features an arid climate with mean annual rainfall of about 200 mm.

Experimentation

The experiment was laid out in randomized complete block design (RCBD) with four replications during summer 2009. The net plot size was 6 m x 2.70 m. Seeds of rice cv. Super basmati were obtained from Rice Research Institute, Kala Shah Kaku. The seeds were osmo-hardened with 2.2% $CaCl_2$ prior to sowing (Farooq *et al.*, 2007). Crop was sown in the first week of July with single row hand drill, using a seed rate of 75 kg ha^{-1} by maintaining 22.5 cm distance between crop rows on a non-flooded, non-puddled aerobic soil. A basal fertilizer dose of 125 kg N, 55 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied. Fertilizers used were urea (46% N), diammonium phosphate (18% N, 46% P_20_5) and sulphate of potash (50% K_2O). The whole phosphorus and potassium and half of nitrogen were applied at the time of sowing. The remaining half nitrogen was applied in two splits at tillering and panicle initiation, respectively.

Three herbicides namely Stomp 455CS (pendimethalin) at 1650 g a.i. ha^{-1} as pre-emergence, Nominee 100SC (bis-pyribac sodium) and Ryzelan 240SC (penoxsulam) at 30 and 15 g a.i. ha^{-1} respectively, were used as early post emergence (15 days after sowing; DAS). Pendimethalin was also followed by either of these herbicides. A weedy check and weed free treatments were maintained for comparison. Spray volume was calibrated using water prior to treatment application. Herbicides were applied using a knapsack sprayer fitted with a t-jet nozzle.

Data on weed dynamics (density and dry weight) were recorded at 30 DAS by two randomly selected quadrats (50 x 50 cm) from each experimental unit. Weeds were counted and clipped from ground surface. Weed dry weight was recorded after drying in an oven at 70ºC for 48 h. Data on rice yield attributes was recorded from 15 randomly selected plants taken from each plot and averaged. Productive tillers (m^{-2}) were counted from two randomly selected sites of each plot and then averaged. Crop was harvested, tied into bundles in respective plots, biological yield of sun dried samples were recorded from each treatment and each experimental plot was manually threshed to determine grain yield and then converted into t ha^{-1}. A random sample of kernels was taken from the produce of each plot. Thousand kernels were counted manually and weighed on an electric balance. Harvest index was calculated as the ratio of grain yield to biological yield and expressed in %.

Kernels were also investigated for various quality characteristics. Kernel length and width was computed with a digital Vernier caliper. Abortive, chalky, opaque and normal kernels were separated by positioning panicle in front of a common electric bulb fitted with a flexible stand as a light source and are expressed in %. Kernel nitrogen was determined by Micro-Kjeldhal digestion followed by ammonia distillation which was then multiplied with factor 5.95 to compute kernel protein (AOAC, 1990). Kernel amylose contents were determined by the method of Juliano (1971). The intensity of blue color was read out in a UV visible spectrophotometer meter (UV-4000, ORI, Germany). Water absorption ratio (WAR) was calculated as suggested by Juliano *et al*., (1965):

$$\text{WAR} = \frac{\text{Weight of cooked rice}}{\text{Weight of raw rice}}$$

Economic and marginal analyses based on variable costs and prevailing market prices of herbicides and rice were carried out to look into comparative benefits of different treatments. Gross income and net benefit (the value of increased yield produced as a result of weed management practices, less the cost of such practices) was computed as described by CIMMYT (1988). Marginal rate of return (MRR) was calculated as under:

$$\text{MRR (\%)} = \frac{\text{Change in net benefit}}{\text{Change in variable cost}} \times 100$$

Statistical analysis

The data collected were subjected to Fisher's analysis of variance technique (Steel *et al*., 1997) using "MSTATC" statistical package (Freed and Scott, 1986) and least significance difference test (LSD test) at 0.05 probability was applied to compare the differences among treatment means.

RESULTS AND DISCUSSION

Weed growth

Weed flora of the experimental site were comprised of *Trianthema portulacastrum*, *Echinochloa colona*, *Dactyloctenium aegyptium*, *Elusine indica*, *Echinochloa crus-galli*, *Spergula arvensis*, *Leptochloa chinensis*, *Cyperus rotundus* and *Cyperus iria*. All the treatments significantly suppressed weed density (Table-1) as compared with control. Sole application of pendimaethalin, bispyribac sodium and penoxsulam furnished 84, 62 and 21% reduction in weed density, respectively. Sequential application of both pre and post emergence herbicides outperformed the sole application, particularly of post emergence herbicides. Pendimethalin followed by either bispyribac sodium or penoxsulam suppressed weed density by >80%

over control and was at par ($P \leq 0.05$) with sole application of pendimethalin.

Significantly lower weed dry biomass over control was observed for all treatments (Table-1). Among sole application of herbicides, pre emergence pendimethalin provided 68% suppression in weed biomass. Post emergence application of bispyribac sodium scored a dry weight suppression of only 29%. Minimum (19%) suppression in weed dry weight was observed for penoxsulam. Pendimethalin followed by bispyribac sodium and penoxsulam inhibited weed dry weight by 80 and 75%, respectively.

Table-1. Influence of sequential application of pre and post emergence herbicides on total weed density and dry weight in dry seeded fine rice.

Treatments	**Weed density ($0.25\ m^{-2}$)**	**Weed dry weight ($g\ 0.25\ m^{-2}$)**
Control	124.80a	249.70a
Stomp 455CS (Pendimethalin) at 1650 g a.i. ha^{-1} (pre-emergence)	19.75 d (-84)	80.66 c (-68)
Nominee 100SC (Bis-pyribac sodium) at 30 g a.i. ha^{-1}(15 DAS)	47.75c (-62)	176.60 b (-29)
Stomp 455CS (pre-emergence) followed by Nominee 100SC (post-emergence)	16.00 d (-87)	49.96 d (-80)
Ryzelan 240SC (Penoxsulam) at 15 g a.i ha^{-1}(15 DAS)	98.00 b (-21)	201.80 b (-19)
Stomp 455CS (pre-emergence) followed by Ryzelan 240SC (post-emergence)	17.75 d (-86)	61.49 cd (-75)
Weed free (hoeing/hand pulling)	0.00 e (-100)	0.00 e (-100)
LSD $P \leq 0.05$	**5.54**	**29.00**

DAS: Days after sowing, Figures given in parenthesis show percent decrease over control, Means with different letters differ significantly at 5% level of probability.

Pendimethalin belongs to dinitroaniline herbicide group that acts as mitotic poison by disrupting cell division through interference with microtubule assembly killing germinating seeds rather than seedlings. Pre-emergence application of pendimethlain was quite effective in reducing weed count and biomass whether applied as a sole treatment or followed in sequence with a post emergence herbicide. Bispyribac sodium and penxosulam act as ALS inhibitors thus retarding the synthesis of branched chain amino acids (Darren and Stephen, 2006). Although these two herbicides provided fair degree of control of broad leaved weed flora comprising chiefly of *T.*

portulacastrum and to some extent grasses like *E. colona* and *E. crus-galli* yet they failed to control grasses emerging late in the season like *D. aegyptium*, *E. indica* and *S. arvensis* (Data not shown). Sole application of these two herbicides as a post emergence treatment failed to avert weed density and dry matter accumulation due to above reason. At the same time, it also reflects the tolerance of *D. aegyptium*, *E. indica* and *S. arvensis* against herbicides with ALS as a target site.

Rice yield and yield components

Data on rice grain yield and its components revealed a positive influence of all weed control treatments over control (Table-2). Highest number of productive tillers (473.80 m^{-2}) was recorded where crop was kept weed free for whole season. A combination of pendimethalin and penoxsulam recorded second highest number (441.80 m^{-2}) of productive tillers, while pendimethalin followed by bispyribac sodium recorded statistically similar number of tillers (372 m^{-2}) as obtained with sole application of pendimethalin (359 m^{-2}). Besides weed free treatment, sequential application of pendimethalin and penoxsulam accounted for maximum kernels per panicle (89.50), 1000-grain weight (22.26 g), grain yield (2.79 t ha^{-1}) and biological yield (10.87 t ha^{-1}). This treatment also reflected statistically similar harvest index as was achieved with weed free treatment.

Table-2. Influence of sequential application of pre and post emergence herbicides on yield and yield components of dry seeded fine rice.

	Productive tillers (m^{-2})	Kernels $panicle^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1	48.50 e	70.50 d	17.58 b	0.15 f	0.75 f	19.30 d
T_2	359 .00c	79.75 bc	18.37 b	2.48 c	9.85 c	25.17 bc
T_3	97.50 e	75.25 cd	18.26 b	1.07 d	4.50 d	24.07 c
T_4	372.00 c	82.00 b	19.72 ab	2.58 c	9.98 c	25.24 ab
T_5	201.00 d	76.00 cd	18.76 b	1.02 e	4.33 e	23.42 c
T_6	441.80 b	89.50 a	22.26 a	2.79 b	10.87 b	25.40 a
T_7	473.80 a	89.75 a	22.27 a	3.01 a	11.87 a	25.43 a
LSD	25.15	5.84	2.76	0.04	0.13	1.05

Means with different letters differ significantly at 5% level of probability, T_1=Control, T_2=Stomp 455CS (Pendimethalin) at 1650 g a.i ha^{-1} (pre-emergence), T_3=Nominee 100SC (Bis-pyribac sodium) at 30 g a.i ha^{-1}(15 DAS), T_4=Stomp 455CS (pre-emergence) followed by Nominee 100SC (post-emergence), T_5=Ryzelan 240SC (Penoxsulam) at 15 g a.i ha^{-1}(15 DAS), T_6=Stomp 455CS (pre-emergence) followed by Ryzelan 240SC (post-emergence), T_7=Weed free (hoeing/hand pulling).

The increase in rice grain yield with efficient weed control treatments may be attributed to better crop growth due to reduced weed-crop competition for any of the growth factor. Sultana (2000) observed that weed infestation of 100-200 weeds m^{-2} reduced paddy yield by 51-64% compared with weed-free conditions. Rice plots without such competition recorded higher number of productive tillers over control because of the greater space capture by rice plants. The canopy closure occurred earlier due to better competitive ability and nutrient efficiency (Baloch *et al*., 2005). Mahajan *et al*. (2009) concluded that herbicides are the most effective means of securing rice yields against weeds. Findings of our studies are in line with those reported by Bhatt and Tewari (2006) who recorded maximum grain yield of rice in weed free plots.

Kernel quality attributes

Kernel length and width are important indices of kernel quality. Long and thin kernels are desirable. A perusal of data (Table-3) indicated an increase in kernel length where weeds were controlled as compared with control. Kernel width, however, remained unaffected. Highest values of abortive (28.75%), chalky (20%) and opaque kernels (23.75%) minimum normal kernels (27.50%) were recorded for control treatment where no weed control method was adopted.

Table-3. Influence of sequential application of pre and post emergence herbicides on quality attributes of dry seeded fine rice.

	Kernel length (mm)	Kernel width (mm)	Abortive kernel (%)	Chalky kernel (%)	Opaque kernel (%)	Normal kernel (%)
T_1	8.45 e	1.43 $^{N.S}$	28.75 a**	20.00 ab	23.75 a	27.50 e
T_2	8.79 b	1.44	12.50 c	22.50 a	16.25 b	53.75 c
T_3	8.80 b	1.44	11.25 c	20.00 ab	23.75 a	42.50 d
T_4	8.81 b	1.45	2.50 e	20.00 ab	15.00 b	62.50 b
T_5	8.12 c	1.43	18.75 b	25.00 a	13.75 b	38.50 d
T_6	9.78 b	1.47	8.75 cd	20.00 ab	5.00 c	67.50 a
T_7	9.80 a	1.48	5.25 de	15.00 b	6.25 c	71.25 a
LSD	0.27	-	5.36	7.49	6.60	4.70

Means with different letters differ significantly at 5% level of probability, $^{N.S}$: non-significant, T_1=Control, T_2=Stomp 455CS (Pendimethalin) at 1650 g a.i. ha^{-1} (pre-emergence), T_3=Nominee 100SC (Bis-pyribac sodium) at 30 g a.i. ha^{-1}(15 DAS), T_4=Stomp 455CS (pre-emergence) followed by Nominee 100SC (post-emergence), T_5=Ryzelan 240SC (Penoxsulam) at 15 g a.i. ha^{-1}(15 DAS), T_6=Stomp 455CS (pre-emergence) followed by Ryzelan 240SC (post-emergence), T_7=Weed free (hoeing/hand pulling).

All other treatments resulted in higher percentage of normal kernels over control. Sequential application of pendimethalin and penoxsulam recorded statistically similar ($P \leq 0.05$) normal kernel percentage as was observed for weed free treatment. Regarding kernel protein contents, this treatment was at par ($P \leq 0.05$) with sole application of pendimethalin or when it was followed by bispyribac sodium (Table-4). It is worth mentioning that increase in yield was accompanied with improved kernel protein contents. Significantly lower amylose contents and higher water absorption ratios over control were recorded for all weed control treatments.

Table-4. Influence of sequential application of pre and post emergence herbicides on quality attributes of dry seeded fine rice.

	Kernel protein content (%)	Kernel amylose content (%)	Water absorption ratio
T_1	6.89 cd	20.60 a	3.23 d
T_2	7.61 bcd	18.05 d	4.05 b
T_3	7.05 cd	19.12 bc	3.88 c
T_4	7.77 bc	18.18 d	4.04 b
T_5	6.50 d	18.01 d	3.86 c
T_6	8.75 ab	18.42 cd	3.93 bc
T_7	9.73 a	19.34 b	4.30 a
LSD	1.21	0.84	0.13

Means with different letters differ significantly at 5% level of probability, T_1=Control, T_2=Stomp 455CS (Pendimethalin) at 1650 g a.i. ha^{-1} (pre-emergence), T_3=Nominee 100SC (Bis-pyribac sodium) at 30 g a.i. ha^{-1} (15 DAS), T_4=Stomp 455CS (pre-emergence) followed by Nominee 100SC (post-emergence), T_5=Ryzelan 240SC (Penoxsulam) at 15 g a.i. ha^{-1} (15 DAS), T_6=Stomp 455CS (pre-emergence) followed by Ryzelan 240SC (post-emergence), T_7=Weed free (hoeing $hand^{-1}$ pulling).

Improved kernel length denotes the greater capacity of source to produce photo assimilates which were then translocated and partitioned into sinks and resulted in longer kernels. Increase in kernel quality attributes may be an out come of better nutrient and water uptake resulting in enhanced fertilization and less number of abortive kernels. Better resource acquisition coupled with reserve mobilization seems one reason for lower number of abortive, chalky, opaque and greater number of normal kernels in treated plots. The improved kernel protein contents may have resulted due to greater fraction of available nitrogen to rice plants in the absence of weeds and its mobilization to panicles.

Table-5. Economic analysis of sequential application of pre and post emergence herbicide in dry seeded fine rice.

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Remarks
Paddy yield	150	2480	1070	2580	1020	2790	3010	kg ha^{-1}
10% loss(paddy)	15	248	107	258	102	279	301	To bring at farmer level
Adjusted paddy yield	135	2232	963	2322	918	2511	2709	10% discount
Income from paddy yield	4388	72540	31298	75465	29836	81608	88043	Rs. 32.50 kg^{-1}
Straw yield	440	7370	600	7400	3320	8080	8860	Kg ha^{-1}
10% loss(straw)	44	737	60	740	332	808	886	To bring at farmer level
Adjusted straw yield	396	6633	540	6660	2988	7272	7974	10% discount
Income from straw yield	279	4975	405	4995	2241	5454	5981	Rs. 30 per 40 kg
Gross income	4667	77515	31703	80460	32077	87062	94024	Rs. ha^{-1}
Hand weeding	-	-	-	-	-	-	8000	Rs. 200/man, 5 man day^{-1} ha^{-1} (8 times)
Cost of penoxsulam	-	-	-		1125	1125	-	Rs. 1125 ha^{-1}
Cost of pendimethalin	-	1625	-	1625	-	1625	-	Rs. 1625 ha^{-1}
Cost of bispyribac sodium	-	-	1250	1250	-	-	-	Rs. 1250 ha^{-1}
Spray Application Cost	-	200	200	400	200	400	-	Rs. 200/man one man day^{-1} ha^{-1}
Spray Rent	-	100	100	200	100	200		Rs. 100 per spray
Cost that varied	0	1950	1550	3475	1425	3350	8000	Rs. ha^{-1}
Net benefit	4667	75565	30153	76985	30652	83712	86024	Rs. ha^{-1}

T_1=Control, T_2=Stomp 455CS (Pendimethalin) at 1650 g a.i ha^{-1} (pre-emergence), T_3=Nominee 100SC (Bis-pyribac sodium) at 30 g a.i ha^{-1}(15 DAS), T_4=Stomp 455CS (pre-emergence) followed by Nominee 100SC (post-emergence), T_5=Ryzelan 240SC (Penoxsulam) at 15 g a.i ha^{-1}(15 DAS), T_6=Stomp 455CS (pre-emergence) followed by Ryzelan 240SC (post-emergence), T_7=Weed free (hoeing/hand pulling).

Table-6. Marginal and dominance analysis of sequential application of pre and post emergence herbicide in dry seeded fine rice.

Treatments	Total cost that vary	Net benefits	Change in cost	Change in net benefits	Marginal rate of return (%)
	Rs. ha^{-1}				
T_1	0	4667	-	-	-
T_5	1425	30652	1425	25985	1823.50
T_3	1550	30153	125	-	D
T_2	1950	75565	400	45412	11353
T_6	3350	83712	1400	8147	581.92
T_4	3475	76985	125	-	D
T_7	8000	86524	4525	9539	210.80

T_1=Control, T_2=Stomp 455CS (Pendimethalin) at 1650 g a.i ha^{-1} (pre-emergence), T_3=Nominee 100SC (Bis-pyribac sodium) at 30 g a.i ha^{-1}(15 DAS), T_4=Stomp 455CS (pre-emergence) followed by Nominee 100SC (post-emergence), T_5=Ryzelan 240SC (Penoxsulam) at 15 g a.i ha^{-1}(15 DAS), T_6=Stomp 455CS (pre-emergence) followed by Ryzelan 240SC (post-emergence), T_7=Weed free (hoeing/hand pulling), D=Dominated.

Lower kernel protein contents in plots treated with penoxsulam may be due to dilution of nitrogen as it was used up by both crop and weeds. Lower amylose contents might be attributed to greater number of normal kernels and more starch compaction. The greater water absorption ratio is an out come of increased kernel dimensions and protein contents which are mostly hygroscopic in nature.

Economic and marginal analysis

All weed control treatments achieved higher net benefits over control (Table-5). Economic analysis revealed that besides weed free treatment, sequential application of pendimethalin and penoxsulam produced maximum net benefits of Rs. 83712. Pendimethalin followed by bispyribac sodium ranked second with net benefits of Rs. 76985 ha^{-1}. Marginal and dominance analyses give a deeper insight into the relative outcome of per unit additional investment made on a specific weed control method. Pre emergence application of pendimethalin was identified as the treatment with highest MRR of 11353% (Table-6). Sequential application of pendimethalin and penoxsulam reflected an MRR of 582%. All other herbicide treatments produced lower MRR or were dominated. Although application of pre and post emergence herbicides in a sequential manner fetched higher net benefits, but higher MRR realized with sole herbicide application only due to higher cost involved in farmer.

The study concluded that pre emergence herbicide application gave effective weed control and good crop stand in direct seeded rice. Depending upon the weed infestation and yield targets, it must be followed by a post emergence herbicide for greater weed control efficacy and higher net returns.

REFERENCES CITED

Adigun, J.A., T.S.O. Lagoke and I.D. Adepke. 2005. Efficacy of selected herbicides for weed control in rain-fed upland rice in the Nigerian Northern Guidea Savanna. Agricultura tropica Et Subtropica, 38: 99-104.

AOAC. 1990. Official methods of analysis. Association of Official Analytical Chemists. 15th Ed., Arlington, Virginia, USA.

Baloch, M.S., G. Hassan and T. Morimoto. 2005. Weeding techniques in transplanted and wet-seeded rice in Pakistan. Weed Biol. Mang., 5: 190-196.

Bhatt, M.D. and A. Tewari. 2006. Losses in growth and yield attributes due to weed composition in transplanted paddy in Terai Region. Sci. World, 4: 99-101.

CIMMYT. 1988. From agronomic data to farmer recommendations: An economics training manual. Mexico. D.F.

Darren, W.L. and E.H. Stephen. 2006. Foliar and root absorption and translocation of bispyribac-sodium in cool-season turf grass. Weed Tech., 20: 1015-1022.

Farooq, M. S.M.A. Basra and N. Ahmad. 2007. Improving the performance of transplanted rice by seed priming. Plant Growth Regul., 51: 129-137.

Freed, R.D. and D.E. Scott, 1986. MSTAT-C. Crop and Soil Science Department, Michigan State University, Michigan, USA.

Gitsopoulos, T.K. and R.J. Froud-Williams. 2004. Effect of oxadiargyl on direct-seeded rice and *Echinochloa crus-galli* under aerobic and anaerobic conditions. Weed Res., 44: 329-334.

Jordan, D.L., D.K. Miller and S.H. Crawford. 1998. Barnyard grass (*Echinochloa crus-galli*) control in dry seeded rice (*Oryza sativa*) with soil applied and post emergence herbicide programs. Weed Tech., 12: 69-73.

Juliano, B.O. 1971. A simplified assay for milled rice amylose. Cereal Sci. Today, 16: 334-338.

Juliano, B.O., L.U. Onate and A.M. Mundo. 1965. Relation of starch compaction, protein content and gelatinization temperatures to cooking and eating quality of milled rice. Food Tech., 19: 1006-1101.

Kim, S.C. and W.G. Ha. 2005. Direct seeding and weed management in Korea. *In* K. Toriyama, K.L. Heong, and B. Hardy (Eds.). Rice is Life: Scientific Perspectives for the 21st Century. IRRI, Philippines and IRCAS, Japan., pp. 181-184.

Mahajan, G., B.S. Chauhan and D.E. Johnson. 2009. Weed management in aerobic rice in Northwestern Indo-Gangetic Plains. J. Crop Impr., 23: 366-382.

Mann, R.A., S. Ahmad, G. Hassan and M.S. Baloch. 2007. Weed management in direct seeded rice crop. Pak. J. Weed Sci. Res., 13: 219-226.

McCauley, G.N., J.H. O'Barr and J.M. Chandler. 2005. Evaluating the efficacy and economics of weed management systems using current commercial herbicides in early and late season treatments alone and in all combinations. *In* Water Management and Weed Science Research in Rice. Research Report. Rice Research Foundation, Texas, USA., pp. 6-7.

Rao, A.N., D.E. Jhonson, B. Sivaprasad, J.K. Ladha and A.M. Mortimer. 2007. Weed management in direct seeded rice. Advan. Agron., 93: 153-255.

Singh, S., J.K. Ladha, R.K. Gupta, L. Bushan and A.N. Rao. 2008. Weed management in aerobic rice systems under varying establishment methods. Crop Prot., 27: 660-671.

Singh, S., L. Bhushan, J.K. Ladha, R.K. Gupta, A.N. Rao, and B. Sivaprasad. 2006. Weed management in dry seeded rice (*Oryza sativa*) cultivated in the furrow irrigated raised bed planting system. Crop Prot., 25: 487-495.

Steel, R.G.D., J.H. Torrie and D. Dickey. 1997. Principles and Procedures of Statistics: A Biometrical Approach. 3rd Ed. McGraw Hill Book Co. Inc. New York. pp., 172-177.

Sultana, R., 2000. Competitive ability of wet-seeded boro rice against *Echinochloa crusgalli* and *Echinochloa colonum*. M.Sc. Thesis. Bangladesh Agricultural University, Mymen Singh, Bangladesh.